Convergence of Information Technology and Control Systems Supporting Paradigm Shift in Social Infrastructure

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PARADIGM SHIFT IN SOCIAL INFRASTRUCTURE

GIVEN the environmental, demographic, and various other issues that social infrastructure faces, taking a consumer-oriented approach is becoming increasingly important.

With energy infrastructure, there is a trend away from rigid service structures that operate unidirectionally from suppliers to consumers and toward collaborative structures in which both sides interact. In the case of smart grids, for example, prosumers(a) act as suppliers of electric power that they generate from renewable or other sources of energy. In Japan, as a response to the power shortages that resulted from the Great East Japan Earthquake, consumers have collaborated with suppliers to keep the electric power system working reliably, including measures such as saving power and managing demand. Inevitably, this collaboration between consumers and suppliers involves the participation of stakeholders with different interests. The managers responsible for the overall system must find an optimum system-wide solution that satisfies different factors, such as balancing supply vs. demand, requirements vs. service levels, and viability vs. economics, and that takes account of numerous constraints, including the different considerations of the environment, suppliers, and consumers.

Meanwhile, in developed economies in particular, social infrastructure equipment is aging. The efficient maintenance of equipment is an important issue for both suppliers and consumers.

Hitachi has experience with the construction of information and control systems for energy, water, transportation, and other forms of social infrastructure. In recent years, Hitachi has been working on the development of social infrastructure systems that converge information and control as part of its Social Innovation Business, the goal of which is, “the global supply of social infrastructure that is safe, secure, and enhanced by the use of information technology (IT)” (see Fig. 1).

This issue of *Hitachi Review* describes Hitachi’s recent work on the technologies and other solutions that it seeks to use in response to the paradigm shift in comprehensively optimized social infrastructure, from the perspectives of both suppliers and consumers.

TRENDS IN SOCIAL INFRASTRUCTURE

This section describes the problems behind the paradigm shift in comprehensively optimized social infrastructure, and the new social infrastructure systems that support this paradigm shift.

Demographic Problems

The United Nations has predicted that global population will increase from approximately 7.0 billion now to around 9.3 billion in 2050. Emerging economies are experiencing not only population growth but also increasing urbanization, with approximately 69% of the world’s population expected to be living in cities by 2050. Similarly, the global gross domestic product (GDP) is expected to grow from $US74 trillion in 2010 to $US141 trillion in 2030, with Asia accounting for roughly half of this total [based on data from the International Monetary Fund (IMF) and other sources collated by the Hitachi Research Institute].

It is anticipated that these changes will also bring problems such as global shortages of fossil fuels, water, and other resources, and the degradation of urban environments due to overcrowding. In seeking to overcome these problems and create sustainable societies, the issues that need to be resolved in

(a) Prosumers
A word coined by combining “producer” and “consumer,” meaning a consumer who also acts as a producer. In the energy field, it refers to consumers who also produce energy, by generating electric power from renewable energy, for example.

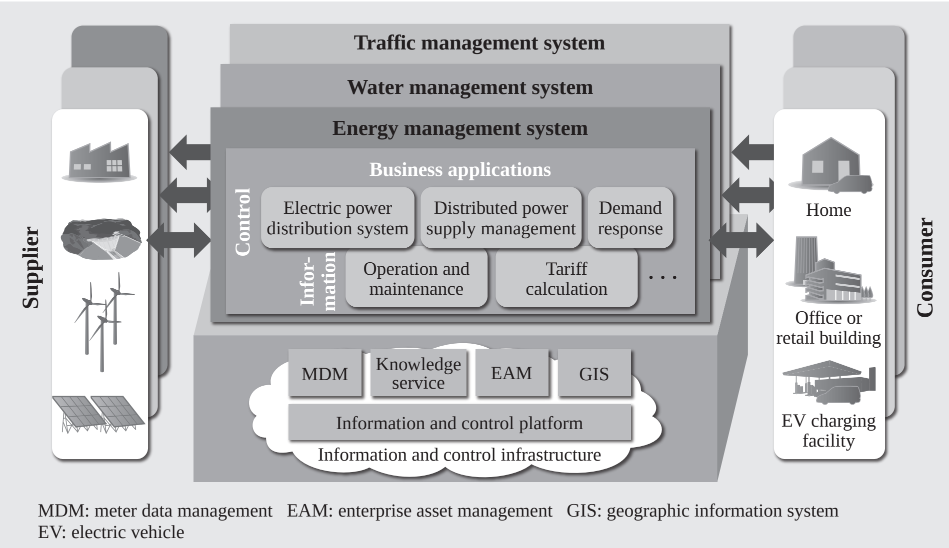

Fig. 1—Social Infrastructure Systems that Converge Information and Control.
Hitachi is using advanced IT to converge information and control systems and help resolve the new issues faced by social infrastructure.

the future are becoming increasingly prominent, including resource diversification, more efficient use of resources, recycling, and making cities more compact(1).

Countries around the world are engaging in a variety of activities aimed at developing new social infrastructure systems for overcoming these challenges. Smart grids are an example of one such measure for dealing with energy resources(2), and progress is being made on initiatives such as the development and demonstration of technology for implementing these power systems, together with policies encouraging the use of renewable energy. Other examples from the field of water resources include measures that support water reuse, including water recycling and large-scale seawater desalination.

Aging of Social Infrastructure

The top priorities for social infrastructure operators (suppliers) include ensuring safety and maintaining service levels, and they have spent a lot of effort on maintenance in the past. Accordingly, there has always been a strong demand for ensuring that maintenance is cost-effective while still maintaining safety and the level of service.

Meanwhile, the problem of aging equipment and machinery on both the supply and demand sides of social infrastructure is becoming increasingly evident in developed economies in particular. In Japan, for example, the quantity of social infrastructure built more than 50 years ago is predicted to increase rapidly in the future. Examples include road bridges, river works, and sewage plants. Inevitably, this is expected to result in an increase in spending on maintenance and upgrades, with predictions that if expenditure continues at current levels, it will exceed the FY2010 budget for new capital spending by the late 2030s(3).

Ensuring that maintenance is both efficient and effective requires total management that extends from the routine through to the medium and long term. Measures for asset management (meaning the efficient management of capital investment in equipment and machinery) have already been introduced(4), and there is a need to extend it to a wide range of equipment and machinery belonging to both suppliers and consumers.

NEW SOCIAL INFRASTRUCTURE SYSTEMS

This section gives an overview of new social infrastructure systems such as smart grids and asset management, and considers the challenges facing their implementation.

Smart Grids

Consumers can turn themselves into prosumers and participate in the supply of electric power through greater production and effective utilization of renewable energy, which also provides a means of resource diversification, and also through energy savings and other measures for using energy efficiently. Because renewable energy is influenced by the natural environment, generation can exceed demand at some times and be inadequate at others. In addition to balancing supply and demand by using batteries to store excess electric power, other ways of dealing with this include “demand response” (DR) whereby suppliers adjust the level of demand by requesting consumers to shift or cut peak demand(5). Fig. 2 shows an example of cutting peak demand for electric power.

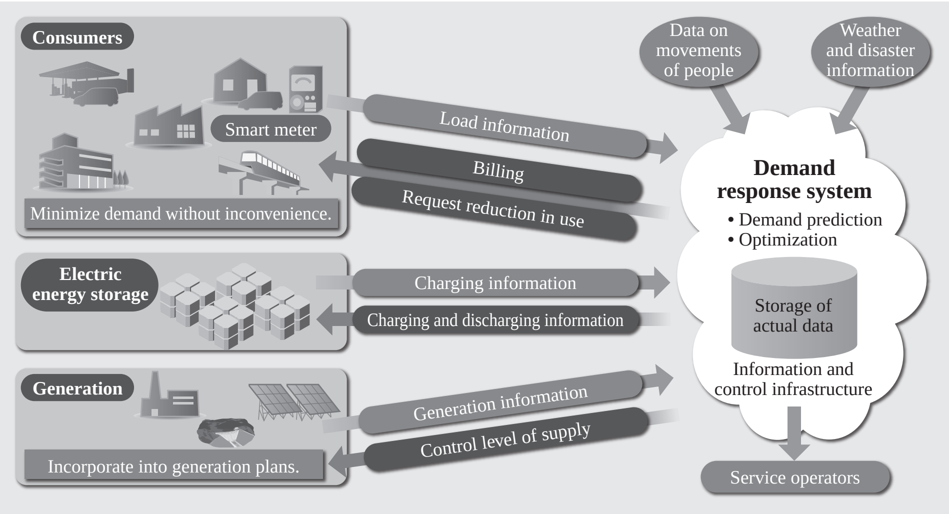

Fig. 2—Demand Response.
"Demand response" means consumers and suppliers cooperating to adjust the balance of supply and demand for electric power by shifting or cutting peaks in consumer power consumption.

The system responsible for overall control obtains information about consumer loads from smart meters and other sensors. If a shortage of electric power is predicted, it then either issues requests to consumers to reduce their power consumption or controls their equipment remotely. The supplier pays incentives to consumers in proportion to the amount by which they reduce power consumption.

Asset Management

While standard practice in the past for maintaining the equipment and machinery used for social infrastructure has been to conduct periodic inspections in person, a more desirable approach is to inspect this equipment as and when needed based on its condition. Fig. 3 shows a new approach to asset management involving the combined utilization of the diverse data obtained from sensors and other measurement devices together with information from other sources. The system presents this composite data in map format and provides an assessment of equipment condition based on analysis and diagnostic functions. It also provides clear information on parameters such as failure rates and maintenance costs for purposes such as capital investment and maintenance planning for equipment and machinery.

Delivering this series of processes in the form of an IT-based service aids asset management for the equipment and machinery used by the suppliers who operate social infrastructure, and also that belonging to consumers such as factories, office buildings, or homes.

Challenges for New Social Infrastructure Systems

Taking a smart grid as an example, the system responsible for overall management has two areas that are difficult to control. The first is the natural environment, including sunlight and wind. Because the

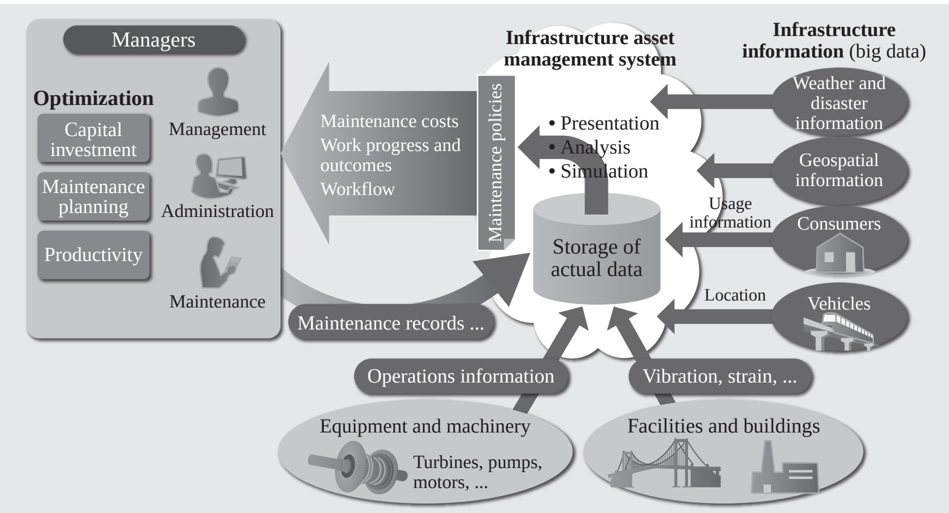

Fig. 3—Asset Management.
Asset management helps improve the efficiency of social infrastructure maintenance through the combined utilization of data obtained from sensors and other measurement devices with various information from other sources.

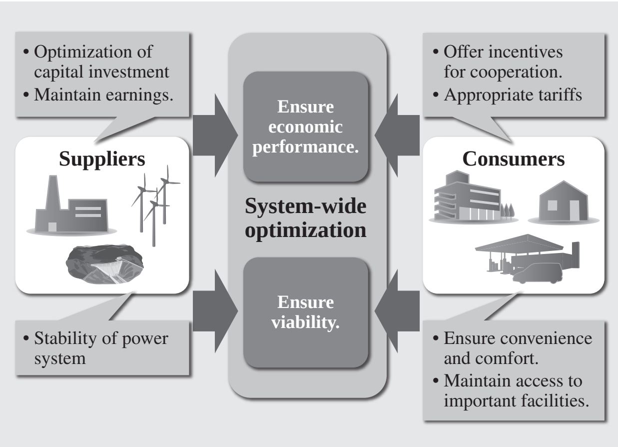

Fig. 4—Requirements of Suppliers and Consumers.
It is necessary to ensure both economic performance and viability in the form of system-wide optimization by satisfying the requirements of both suppliers and consumers, simultaneously and in realtime.

amount of electric power generated from these sources cannot be determined in advance, there are concerns about their impact on the power system. Accordingly, the installation of large amounts of renewable energy capacity will need to be accompanied by accurate techniques for predicting power output and estimating the status of the grid.

The other difficulty relates to how suppliers handle the requests they issue to consumers. If variations in the output of renewable energy are to be dealt with by adjusting demand, there is a risk that these adjustments will be inadequate because of a mismatch between what the supplier requests and the specific requirements of different consumers. This means there is a need for arrangements that are beneficial to both suppliers and consumers, and that satisfy requirements such as grid stability (as required by the supplier) and the provision of incentives (that benefit the consumer) simultaneously and in realtime[(b)] (see Fig. 4).

Also, asset management requires technology for the collection and analysis of information from large numbers of sensors so that it can accurately assess the status of the machinery and other equipment and utilize this information for timely maintenance. It is also necessary to deliver services in ways that suit the different phases of the social infrastructure lifecycle, including installation, growth, and maturity.

(b) Realtime
The term “realtime” is used here to indicate that processing is executed as soon as it is requested. Control systems typically need to operate with cycle times in the range of milliseconds. In this issue of *Hitachi Review*, however, “realtime” is used in the wider sense of the on-demand delivery of the required services when they are needed.

A common feature of these functions, whether it be predicting the natural environment, analyzing consumer behavior patterns, or collecting large quantities of data for analysis and service delivery, is that they all require the use of advanced IT.

USE OF ADVANCED IT TO CONVERGE INFORMATION AND CONTROL

The recent breakthroughs in information platforms described below mean that, compared to the past, very large amounts of computing resource are now available at low cost.

(1) In addition to improvements in per-server performance, computing power with high speed and capacity has been made available by the emergence of technologies for large-scale distributed processing such as virtualization and cloud architectures.

(2) Fixed line and wireless communications with high speed and capacity, such as optical and machine-to-machine (M2M) communication systems, have become available, allowing measurement data to be collected in realtime from smart meters and other measurement devices.

(3) With advances in semiconductor technology, a wide range of sensors suitable for use in social infrastructure have been made smaller and more sophisticated with a wider range of functions, including radio frequency identification (RFID) tags, temperature sensors, strain gauges, and gas detectors.

It is easy to imagine how this latest advanced IT can be utilized in information and control systems to resolve the issues facing new social infrastructure systems. Fig. 5 shows the system configuration framework. The framework includes use of high-capacity local area networks (LANs), M2M communications, and sensors and other measurement devices installed in the social infrastructure to collect information from it in much greater quantity and level of detail than was ever possible in the past. In other words, this is what has come to be known as “big data.”

The information and control infrastructure is made up of standard functions for the management and analysis of this big data, and for the effective use of the associated information and knowledge in business applications. Specific functions include meter data management (MDM) for collecting and managing sensing data from sensors and other measurement devices and supplying it to other systems; knowledge service functions that perform analysis, diagnosis, and simulation of this data so that it can be put to

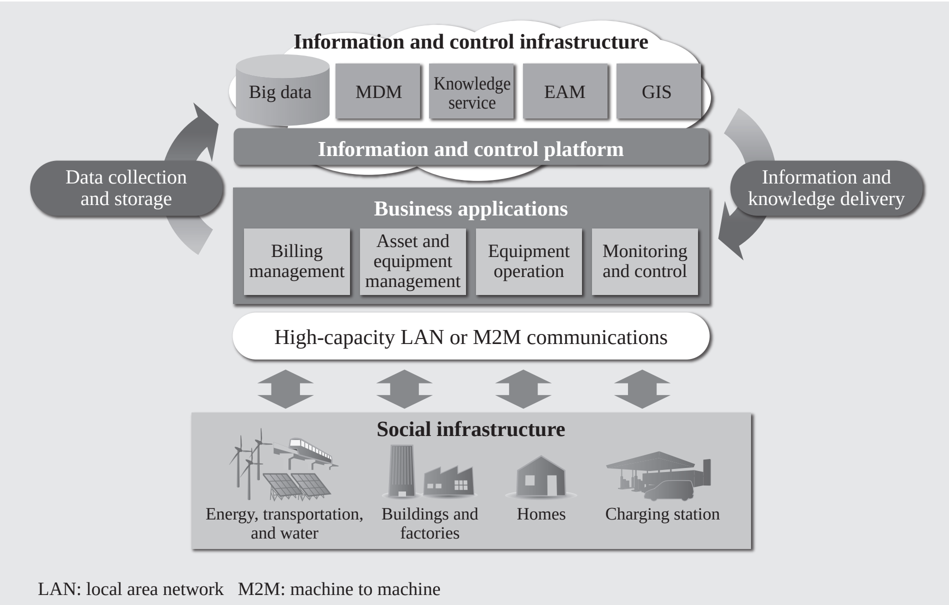

Fig. 5—Framework for Systems that Utilize Advanced IT to Converge Information and Control.
"Convergence" means that information and control functions interoperate in realtime to provide suppliers and consumers with added value by completing sophisticated tasks that were not possible in the past.

practical use; enterprise asset management (EAM) for managing the various equipment (assets) used in social infrastructure; and geographic information systems (GISs) that use maps for the visual display of information about assets and the results of analysis and diagnostic processing. The information and control platform not only coordinates these non-application-specific functions and business applications, it also supports efficient operation by coordinating the operation of different social infrastructure.

In these ways, information and control infrastructure incorporating the latest advanced IT in its back-end systems supplies valuable information and knowledge required for information and control applications in realtime. This allows information and control functions to interoperate in realtime (what Hitachi calls "the convergence of information and control") and provides suppliers and consumers with added value by completing sophisticated tasks that were not possible in the past. That is, it makes it possible both to maintain power system stability on smart grids and deliver incentives to consumers, simultaneously and in realtime, and also to provide for timely maintenance of social infrastructure by performing analysis and diagnostics on large quantities of sensing data.

Meanwhile, infrastructure operators and equipment suppliers in Japan have worked together to develop different system technologies and build social infrastructure systems. As an equipment supplier, Hitachi has experience in the construction of social infrastructure systems in a variety of fields.

The use of big data for analysis, diagnosis, and simulation as described above to identify value requires knowledge and know-how from the relevant industries. Hitachi aims to work with infrastructure operators to supply operational know-how by drawing on its past experience in the construction of social infrastructure systems.

ACTIVITIES BY HITACHI

Hitachi is working on packaging the products it offers for social infrastructure systems created from a convergence of information and control by expanding beyond systems and components to also include services, and is implementing this strategy through activities such as smart grid demonstrations in Japan and elsewhere. The following sections introduce the technologies and other solutions covered in this issue of *Hitachi Review*.

Energy Solutions

Some of the functions of demand response are already in use overseas, and activities in Japan include four regional demonstrations[(c)]. Also, a service for minimizing peak demand was introduced in 2012 in response to the constrained supply of electric power, with Hitachi participating as an operator of demand response schemes. This involved a service for limiting consumer demand through coordination with aggregators that handle energy management for groups

(c) Four regional demonstrations
These smart community demonstrations are being undertaken at Kitakyushu City, Kansai Science City (Keihanna), Toyota City, and Yokohama City. The energy management system demonstrations are currently in progress and combine home energy management systems (HEMS), building and energy management systems (BEMS), EVs, and other technologies for applications that include demand response and giving users access to information on energy use.

of buildings in response to requests from electric power companies to change the level of demand.

Water Solutions

Hitachi's activities include seawater desalination and water treatment businesses in India and elsewhere. It is also promoting its Intelligent Water System concept for using advanced IT in water infrastructure (such as water treatment and distribution facilities) as a way of overcoming problems such as water shortages, the aging of water infrastructure, and dwindling numbers of technical personnel. This focuses on water to optimize the overall system for the flow of water, energy, and information, and includes development work in the fields of business management, water infrastructure operation, water treatment control, and water treatment equipment (see page 364).

Transportation Solutions

Hitachi has experience with the implementation of intelligent transport systems (ITS) and telematics systems that deliver a variety of information from center systems to vehicle-mounted devices. To help resolve urban environmental problems, Hitachi is also participating in demonstrations that provide operational support for the reduction of carbon dioxide (CO_2) emissions from public transportation. Meanwhile, the Japan-U.S. Island Grid Project of the New Energy and Industrial Technology Development Organization (NEDO) currently in progress in Hawaii is trialing the coordination of EV management with the electric power distribution system so that EVs can be used to make efficient use of renewable energy (see page 353).

Operation and Maintenance Services

To ensure the efficient operation and maintenance (O&M) of social infrastructure, Hitachi is also proceeding with the development of O&M services that utilize advanced IT to supply extensive know-how and knowledge in the field of operation and maintenance. Social infrastructure has been developed to different levels in different parts of the world. The objectives of these O&M services are to work in collaboration with infrastructure operators to supply highly flexible services for this social infrastructure, and to deliver the services in ways that can adapt to the circumstances in each country, such as changes in the business environment faced by social infrastructure operators, and in accordance with the relevant stage of development such as installation, growth, or maturity. An article in this issue describes an example application of these services to a railway system (see page 370).

Knowledge Service Functions

Hitachi is developing knowledge service functions that supply operation and maintenance services and industry-specific solutions for social infrastructure. Simulation technologies being developed to support energy solutions include a smart grid simulator and energy network simulation techniques that handle both electric power and heat (see page 376).

To make use of big data, Hitachi is working on the development of "things," "people," and "concepts" analysis techniques and services. An article in this issue describes an application for big data involving equipment such as gas turbines and building facilities that deals with "things" (equipment and machinery) from the perspectives of information and control (see page 384).

Information and Control Platform and Information Security Technology

Interoperation between different types of social infrastructure such as electric power and transportation provides various forms of value to consumers. Hitachi is developing information and control platforms that provide a wide range of data required by systems in realtime while also maintaining the interconnectivity, reliability, and expandability of the interoperating social infrastructure (see page 389).

Maintaining security is an important consideration for social infrastructure systems. Hitachi has experience in the development of various systems and other technologies for security, with current cyber security developments for social infrastructure including advanced encryption techniques that impose a low processing load, and security technologies that reduce the operational load on social infrastructure systems (see page 397).

Global Deployment

The public and private sectors in Japan have increasingly been working together to deploy Japanese social infrastructure in emerging economies and other parts of the world. There is also a rapidly strengthening global trend toward requiring social infrastructure to comply with international standards. If Japan is to proceed with the deployment of its social infrastructure internationally, there is a need to work on service standards that define the scope of different businesses so that they can be demarcated. Japanese social infrastructure operators and equipment suppliers are working with the relevant government agencies on the presentation of proposals to the International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), International Telecommunication Union (ITU), and other international standards bodies in fields such as smart grids and smart cities. Hitachi is also cooperating with these activities (see page 402).

BUILDING SMART INFRASTRUCTURE

The topics covered in this article have included the macro trends associated with social infrastructure, the issues that need to be resolved to achieve a paradigm shift in social infrastructure, and what Hitachi is doing to create a convergence of information and control that utilizes advanced IT. This advanced IT (specifically, large-scale distributed processing technology) is used in the field of information systems, including data centers, search engines, and smartphone applications. However, the deployment of these technologies in the information and control systems that support social infrastructure such as electric power, water, and transportation is a task for the future, and the social impact and other wider consequences of this has yet to become sufficiently clear. Hitachi has experience in the supply of technologies such as those for highly reliable realtime techniques, network control, and autonomous decentralized systems. Hitachi intends to help overcome various problems and other challenges that manifest on a global scale by continuing to focus on advanced IT for these technologies and on implementing information and control convergence systems that are as closely interlinked as their name suggests.

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